# Carbon Climate Feedbacks Analysis w the NCAR C-CCSM1

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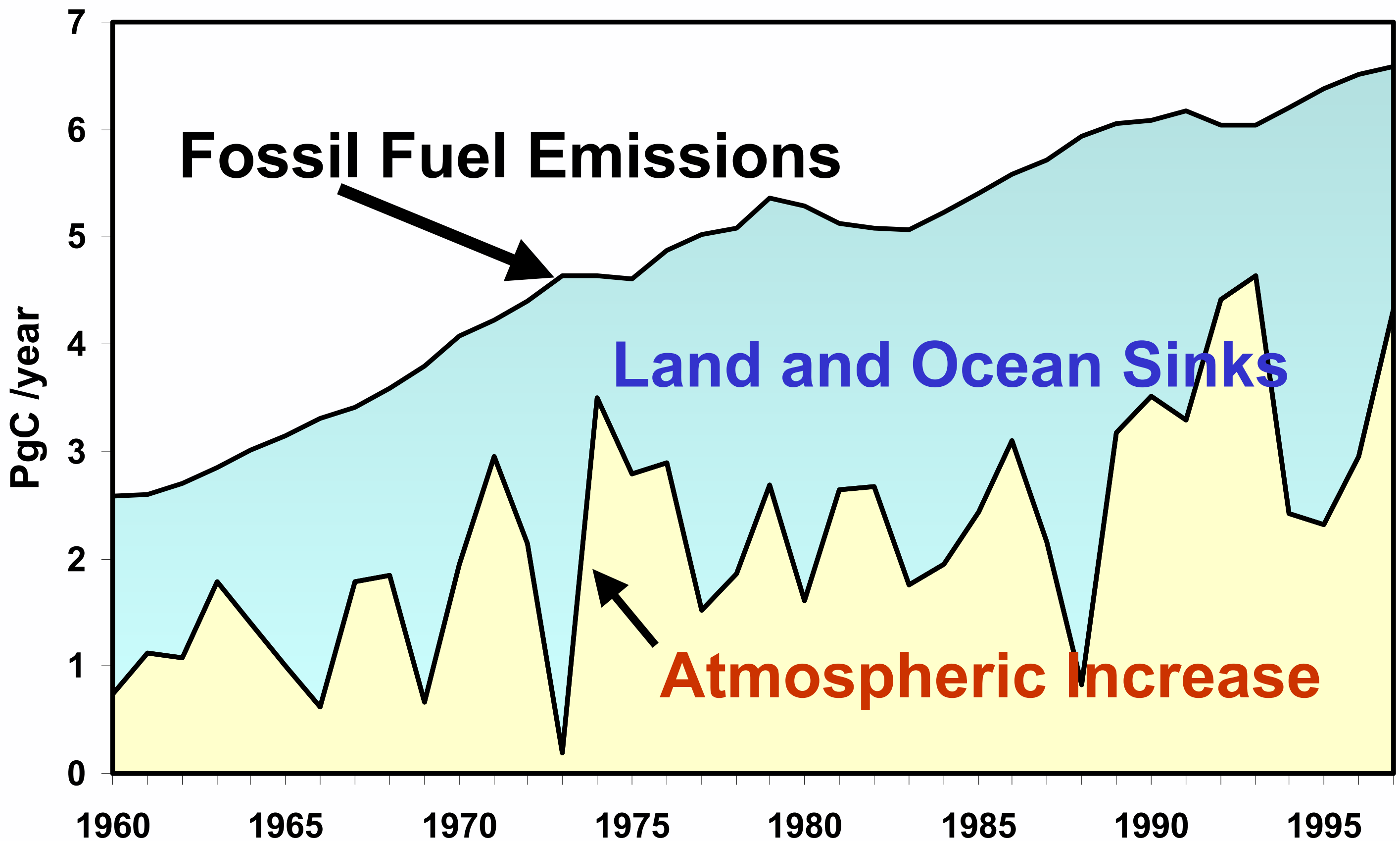
# Contemporary Atmospheric $CO_2$ Budget

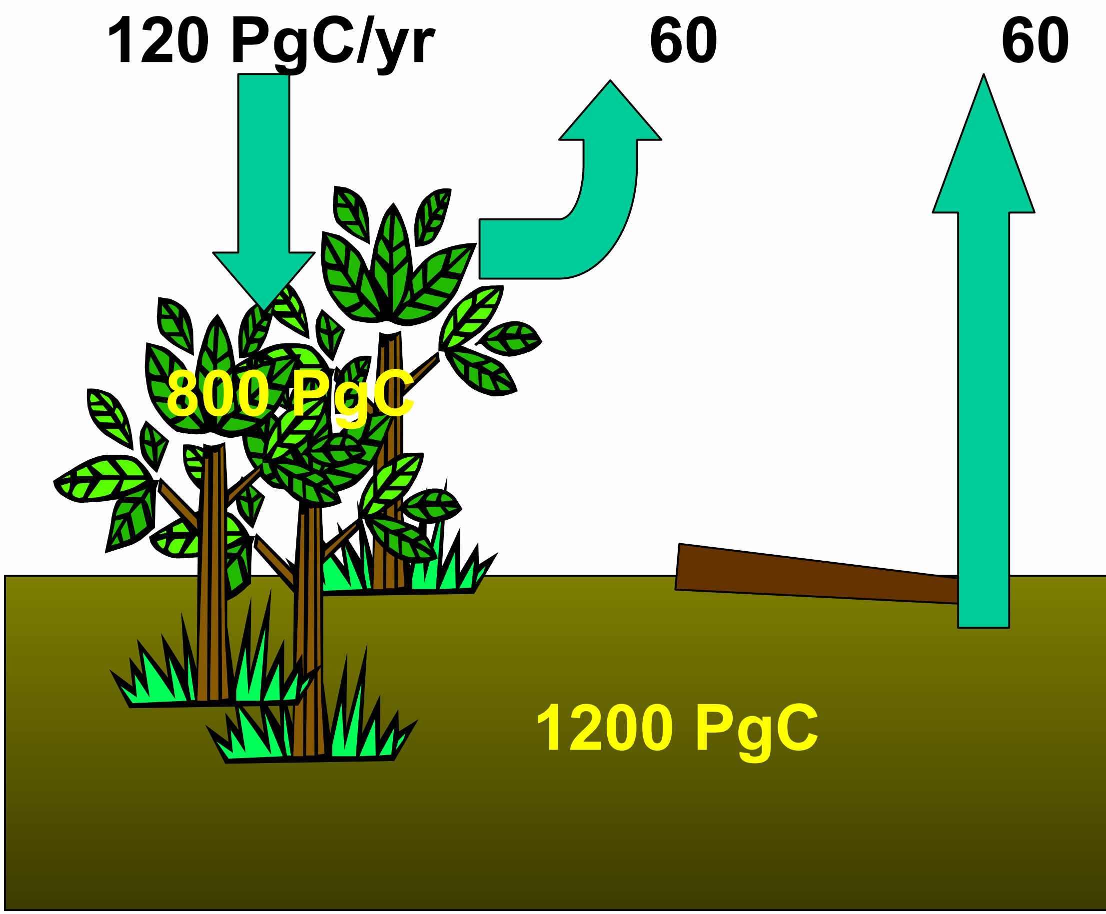



Land & ocean sinks ~ 50% of FF emission
sensitive to climate perturbations

Will the warming increase or decrease the capacity of the land and ocean to store carbon?

# Terrestrial Carbon Cycle

- Growth, mortality, decay
- Population: {ages}
- Photosynthesis (climate, $CO_2$, soil $H_2O$, resource limitation)
- Decay (T, soil $H_2O$,..)



# How would $CO_2$ and climate co-vary?

## Suppose there is warming…

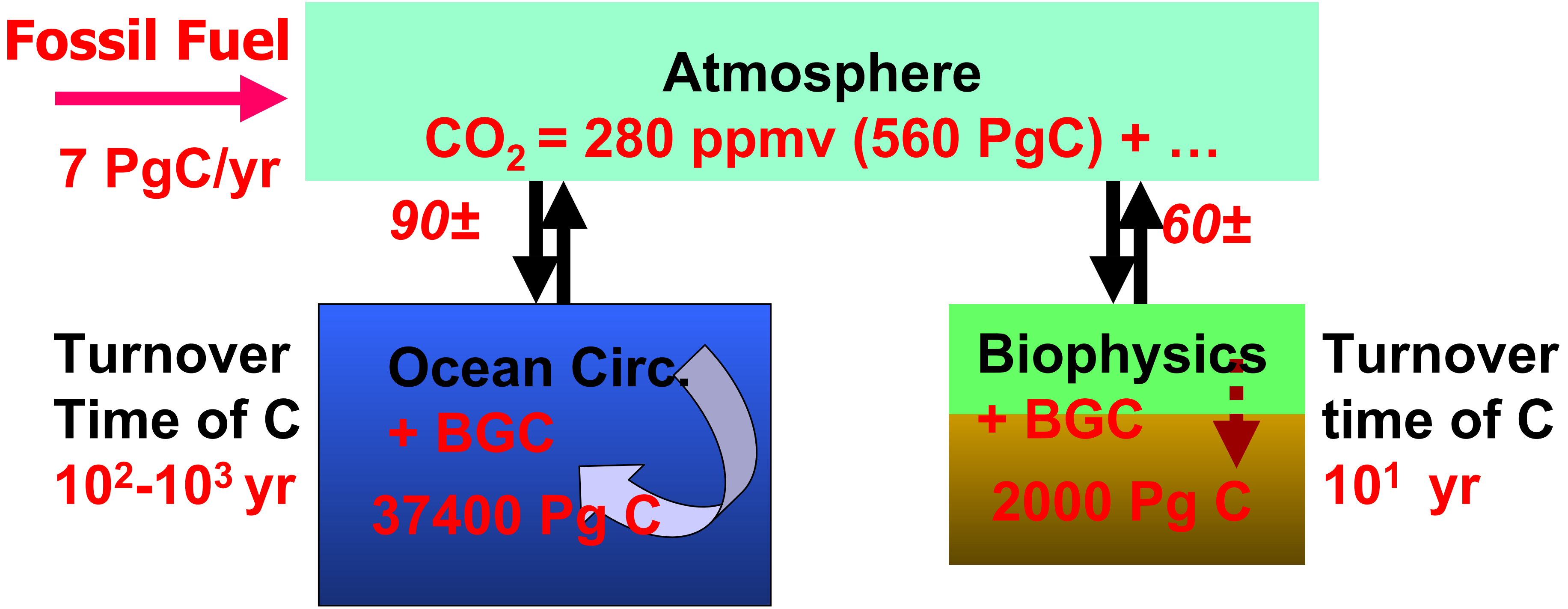
**Atm $CO_2$ would increase because:**

- Warming may enhance decomposition
- Increased ocean stratification → more carbon in mixed layer → reduced air-to-sea flux
- ….

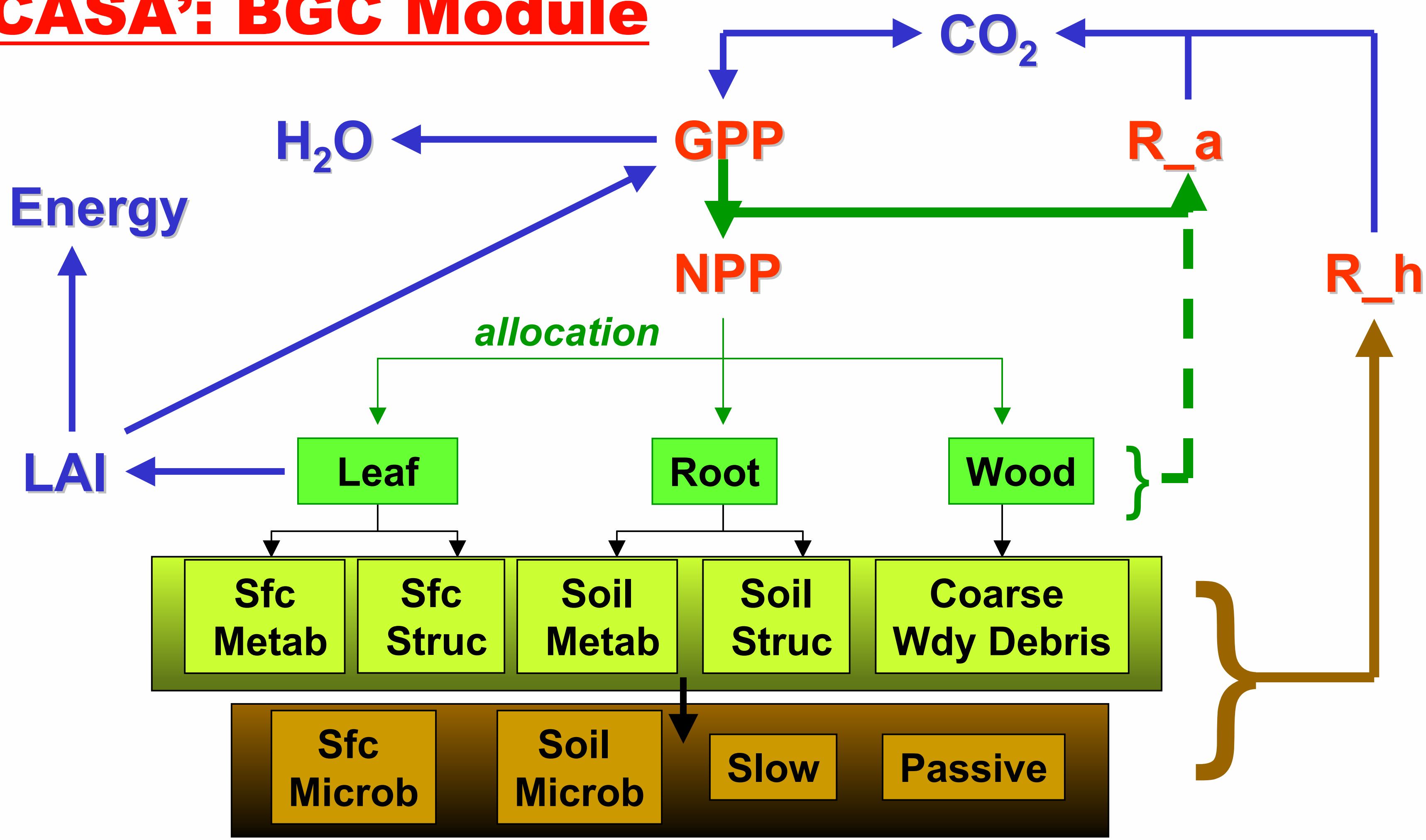
**Atm $CO_2$ would decrease because:**

- warming may enhance photosynthesis
- Enhanced marine productivity and export

# Modeler's (Simplistic) View of the Global C Cycle



# CASA': BGC Module




**Based on coupling of CASA BGC & LSM Land Biogeophysics**

- GPP/NPP from AGCM
- dynamic allocation
- prognostic Leaf Area Index (LAI) and phenolgy

# Iron-Carbon Biogeochemistry Model (OCMIP')

**OCMIP**

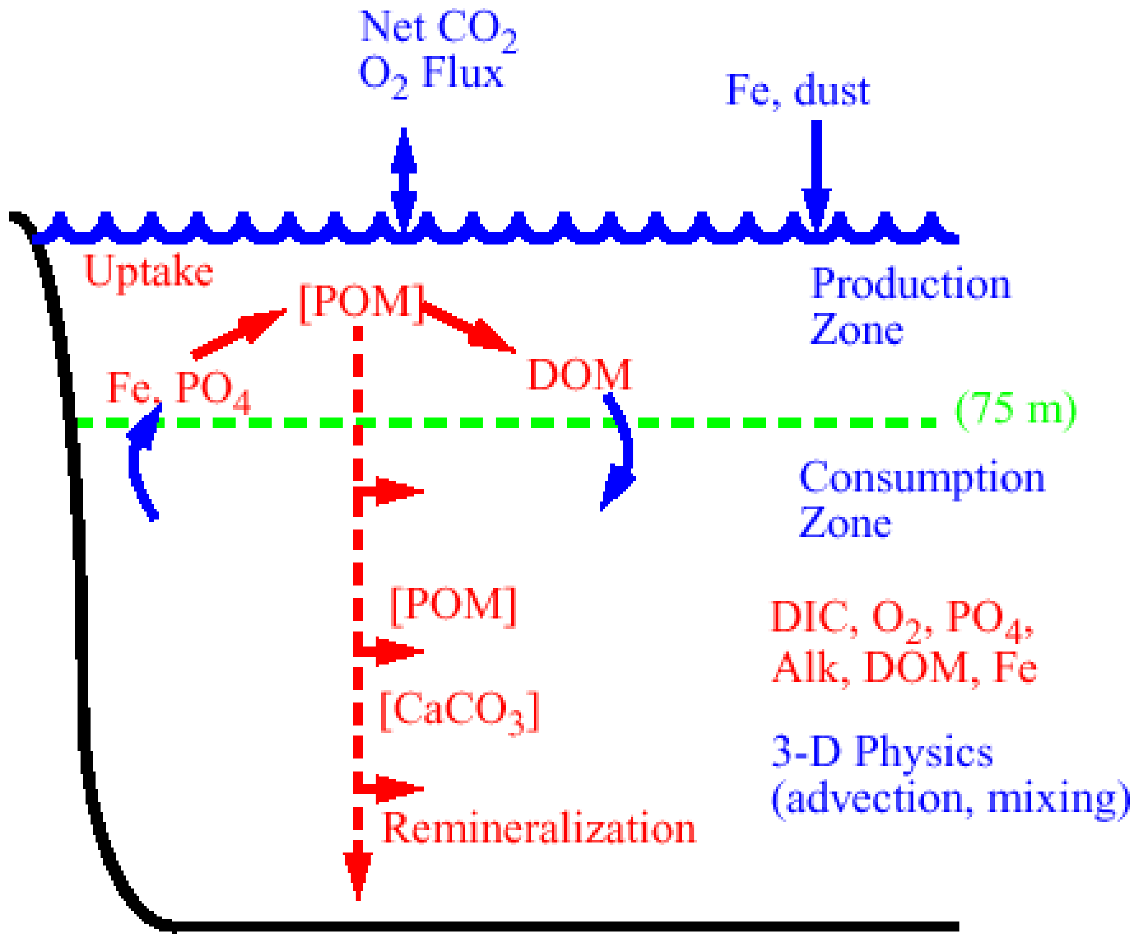
**-carbonate thermodynamics & air-sea fluxes**

**-diagnostic biotic model**

**Enhancements**

**-replace $PO_4$ restoring w/ prognostic export flux**

**-incorporate Fe limitation and Fe cycling**



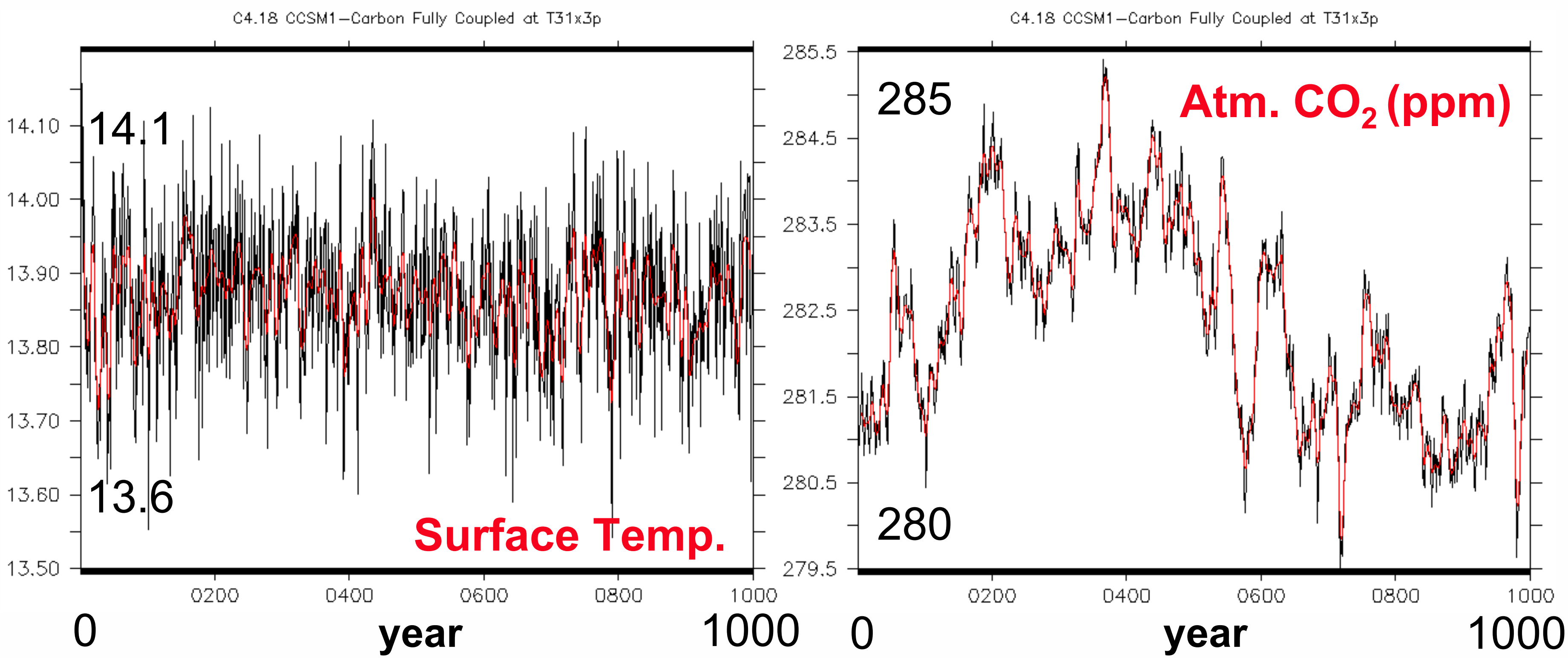

-Production f(temp, light, $PO_4$, Fe)

-Fixed Redfield Ratios linking C,P, $O_2$

-Martin et al. Particle Remineralization Curve

-Semi-labile DOM only

# Multi-Century Coupled Carbon/Climate Simulations



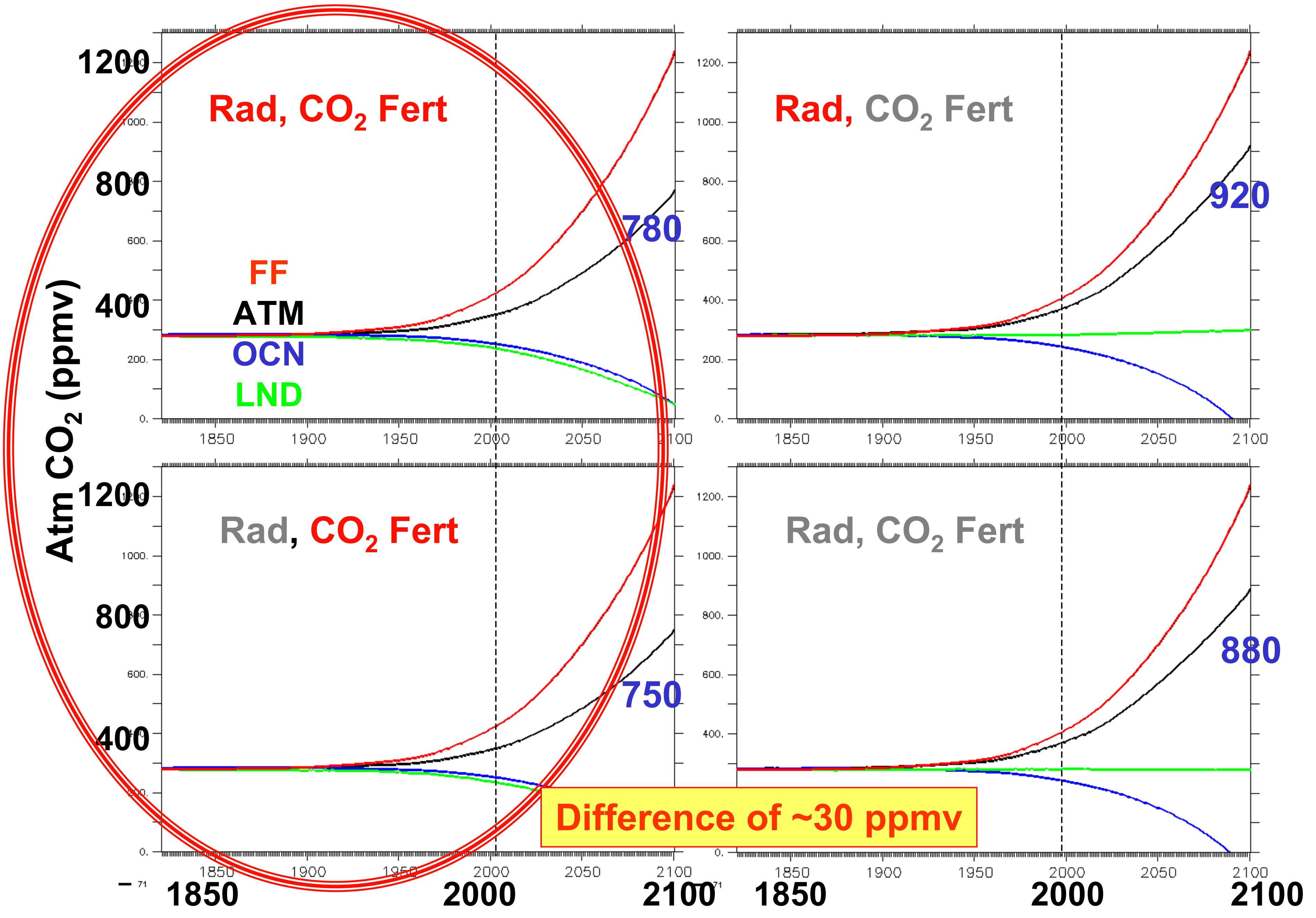

- “Stable” carbon cycle and climate over 1000y ☺
- Net Land+ocean inventory: ±2 PgC
- Natural climate modes (detection/attribution)
- Baseline for climate projections/fossil fuel perturbations

# Idealized Expts: Fixed land cover

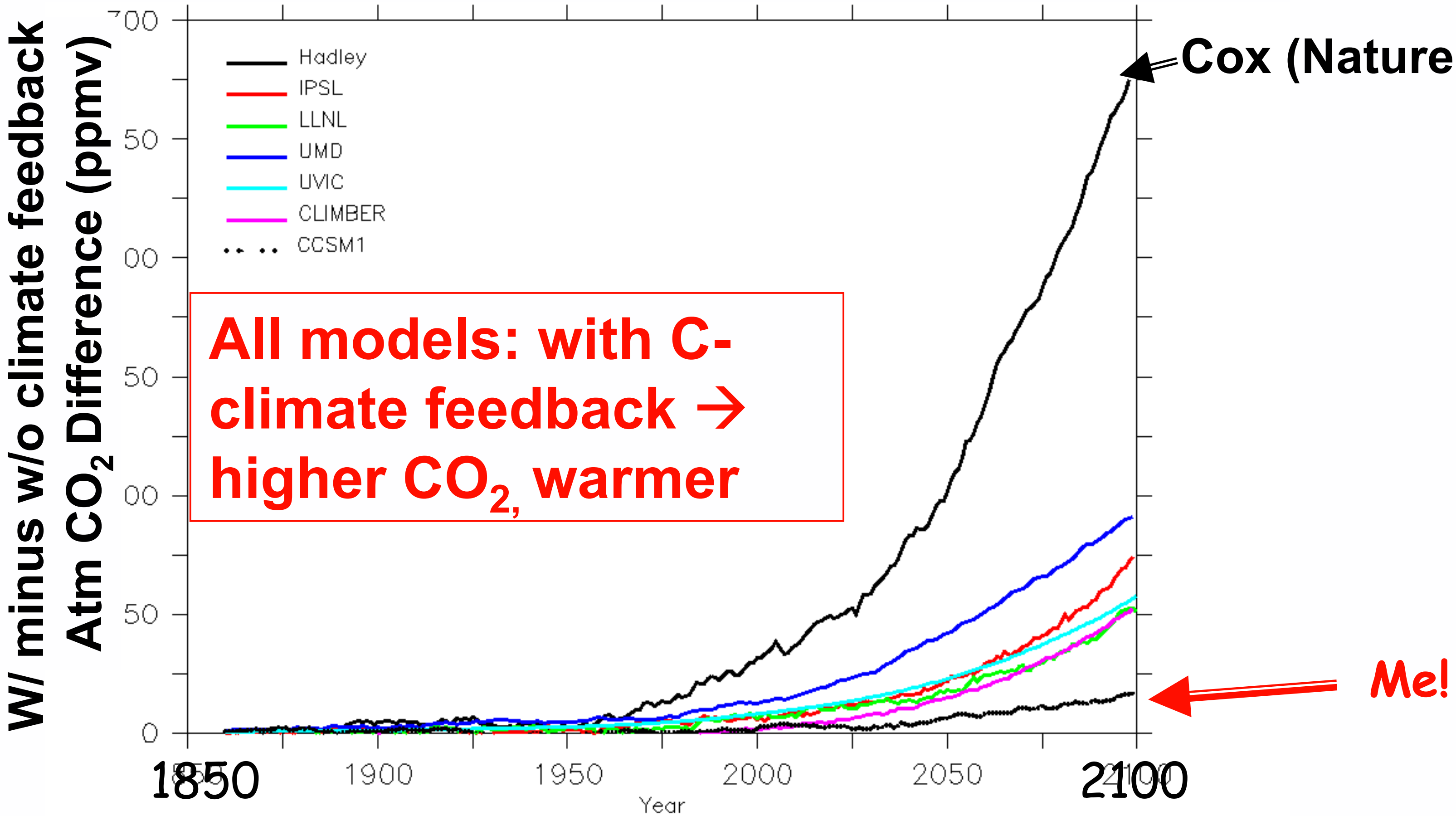
**Given: historical FF + SRES A2 emission**

- Rad_on, $CO_2$Fert_on
  - Coupling between climate and C cycle
  - Ocn senses incr $CO_2$ in atm and changing circulation
- Rad_off, $CO_2$Fert_on
  - Climate "sees" 283 ppmv in atm
  - C cycle "sees" control climate & circulation
- Rad_on, $CO_2$Fert_off
- Rad_off, $CO_2$Fert_off

# Atm $CO_2$ Budgets: Historical + SRES A2 FF Emission

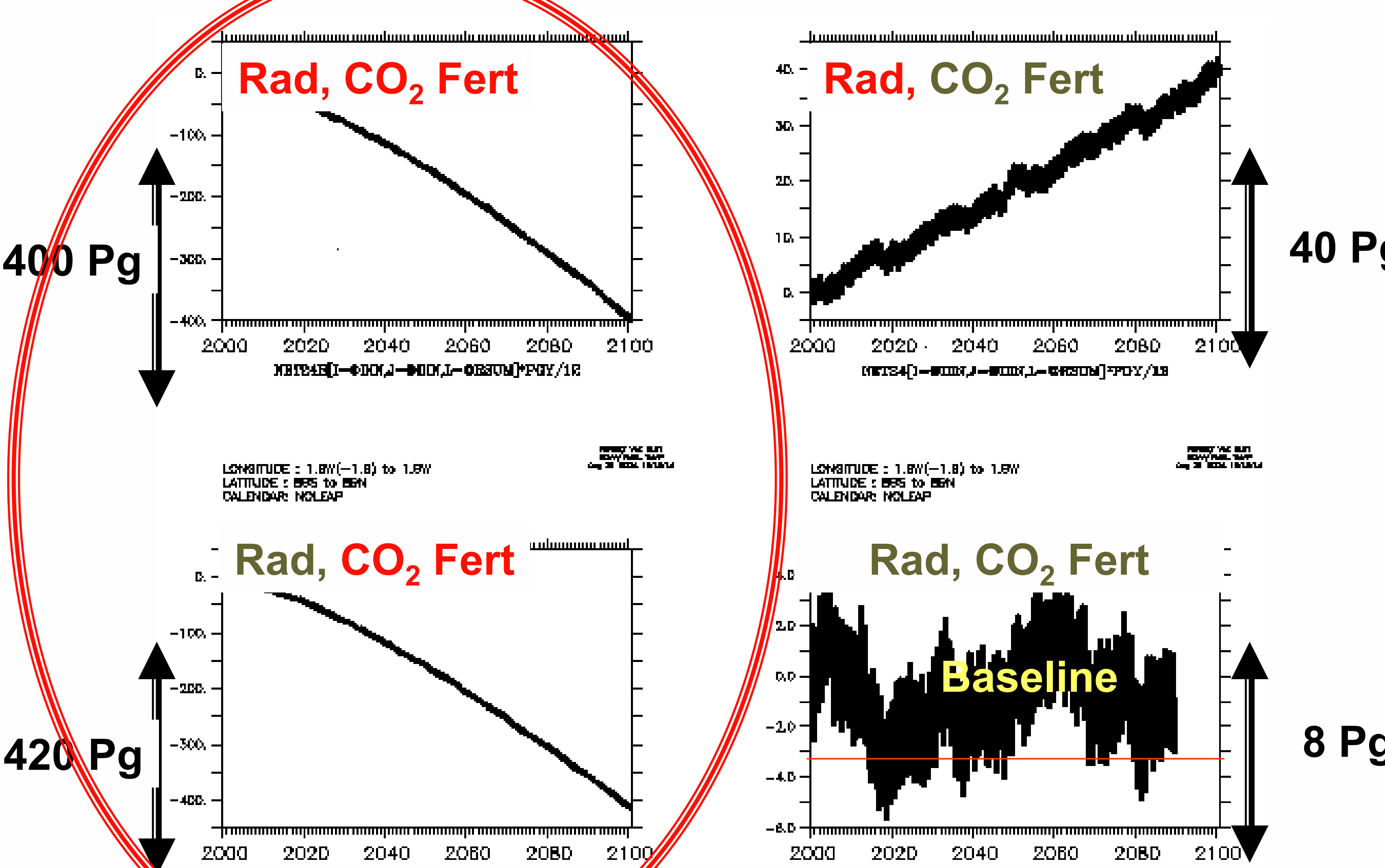


# WCRP-IGBP Coupled Carbon Cycle Climate (C4MIP): FF=SRES A2, BYOM

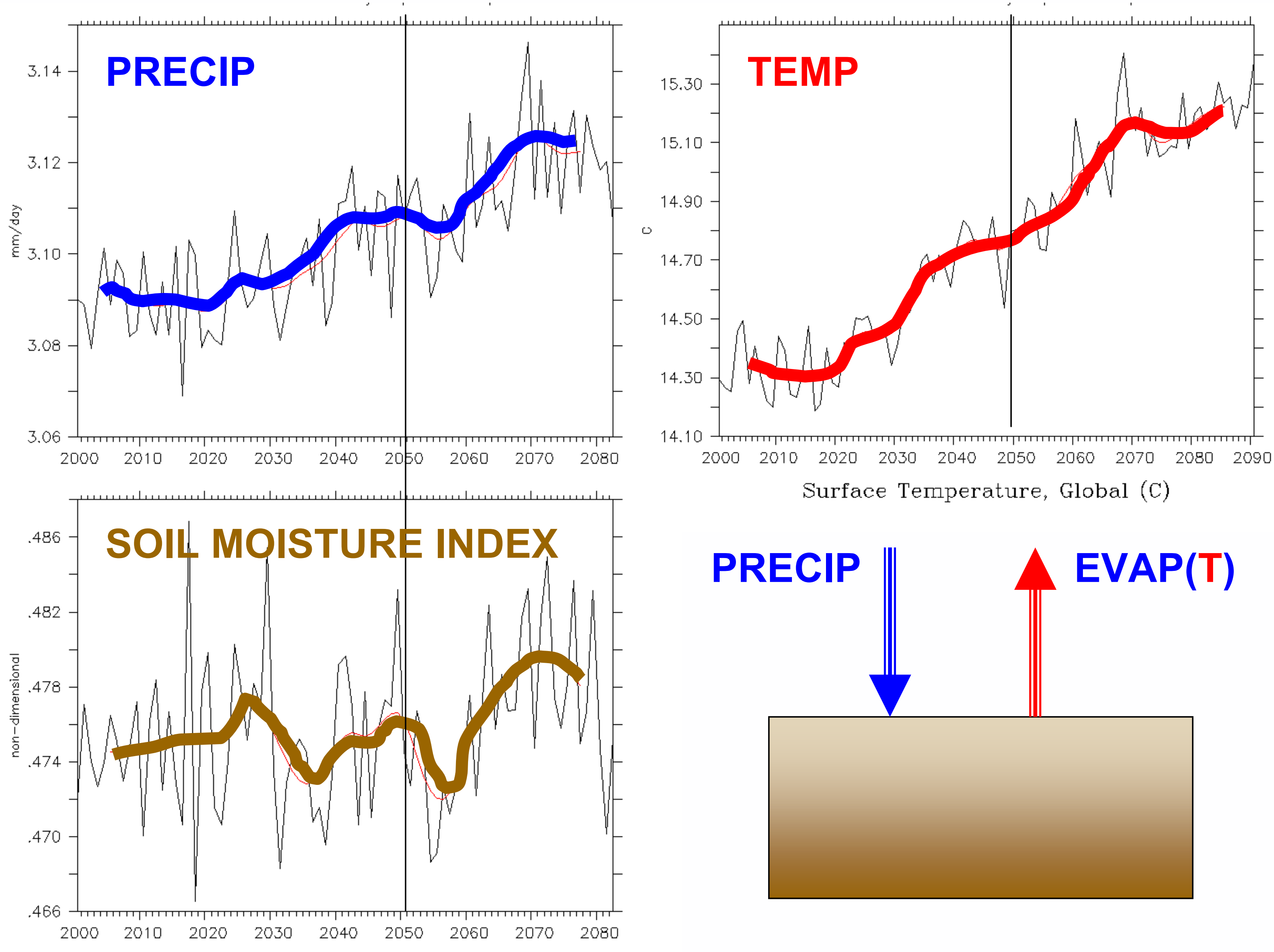



C4MIP Meeting, Berkeley 2004/12/12

# Cumulative land sinks



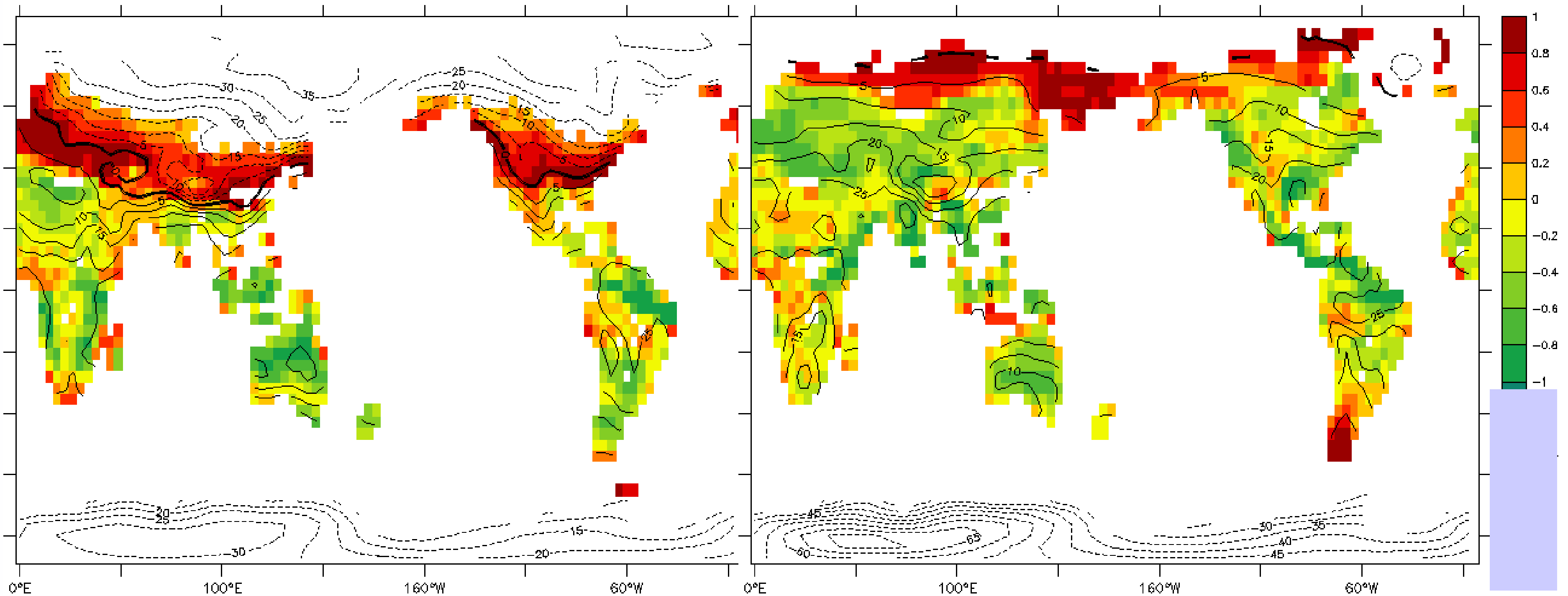

**w/ & w/o climate feedback → similar land uptake**




**Warming > Precip incr → Drying → Slows C Sink**

# Correlation: {ΔT, Δ soil moisture index}

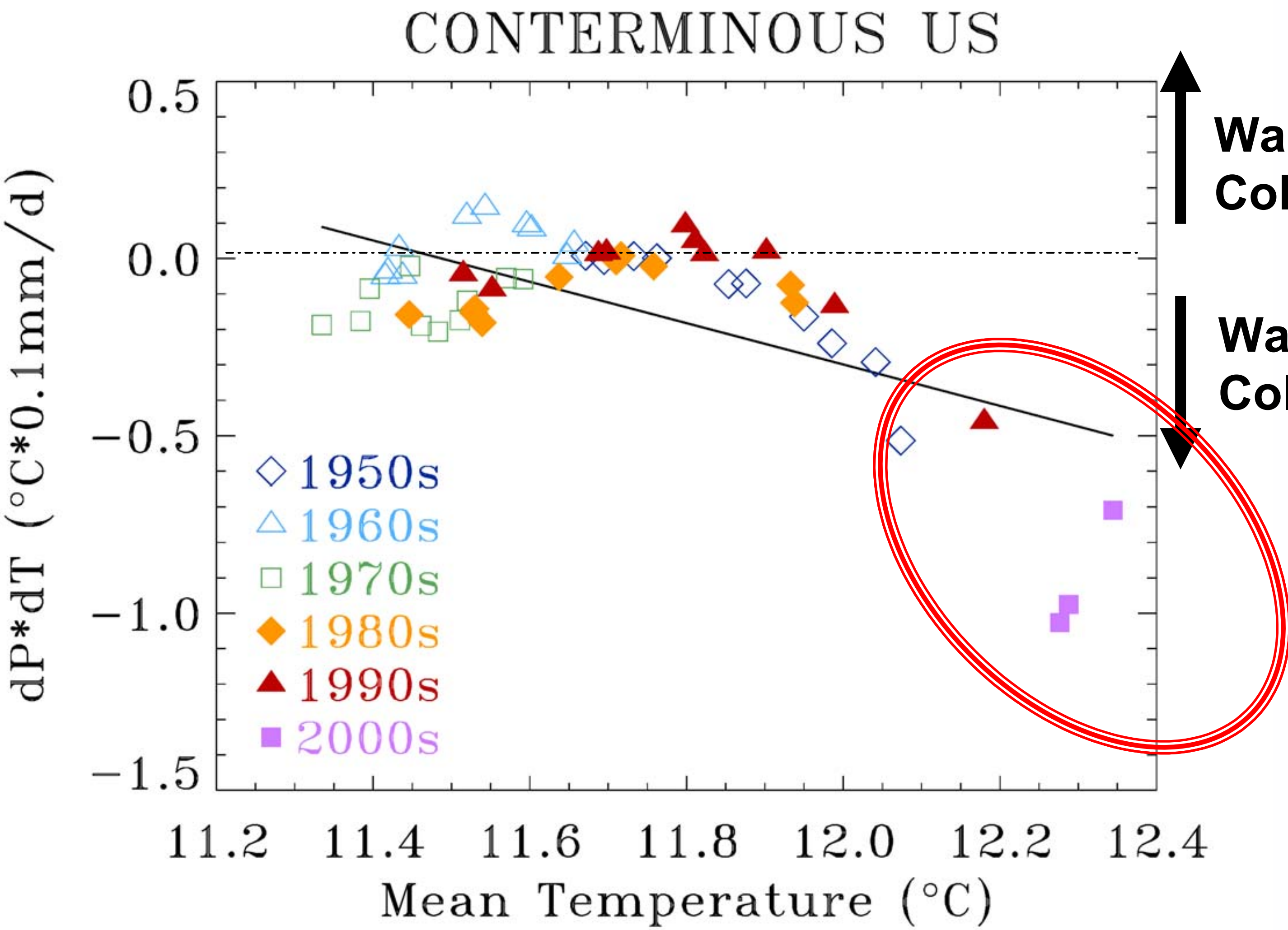
## CCSM1-Carbon Control Simulation




**Positive correlation → warmer-wetter; or cooler-drier**

**Negative correlation → warmer-drier; or cooler-wetter**

# Observed Co-Variations of ΔT and ΔPrecip

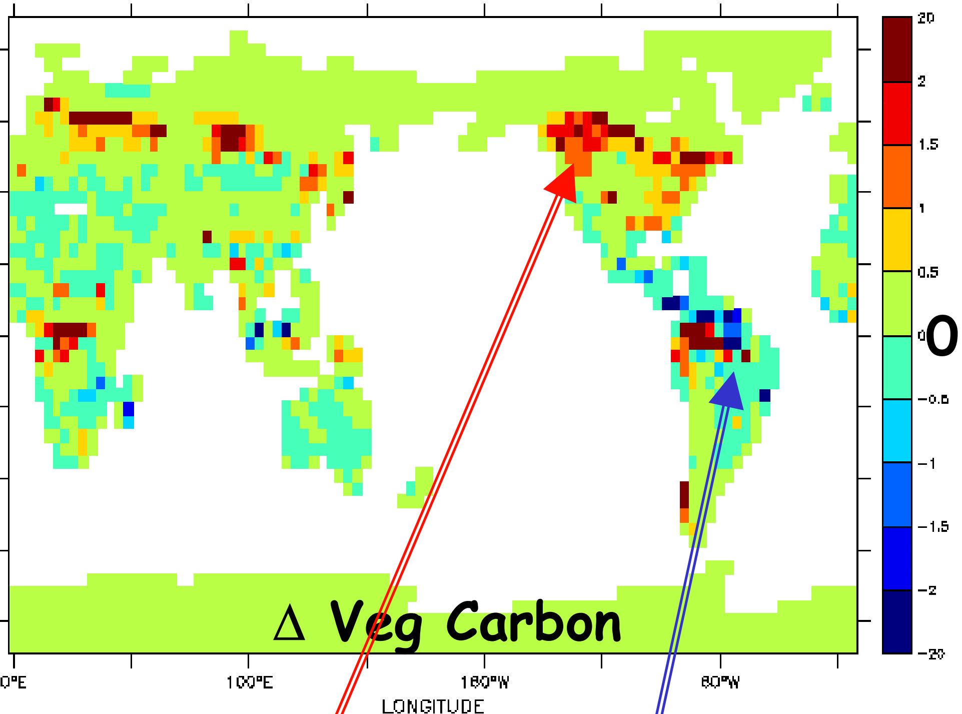


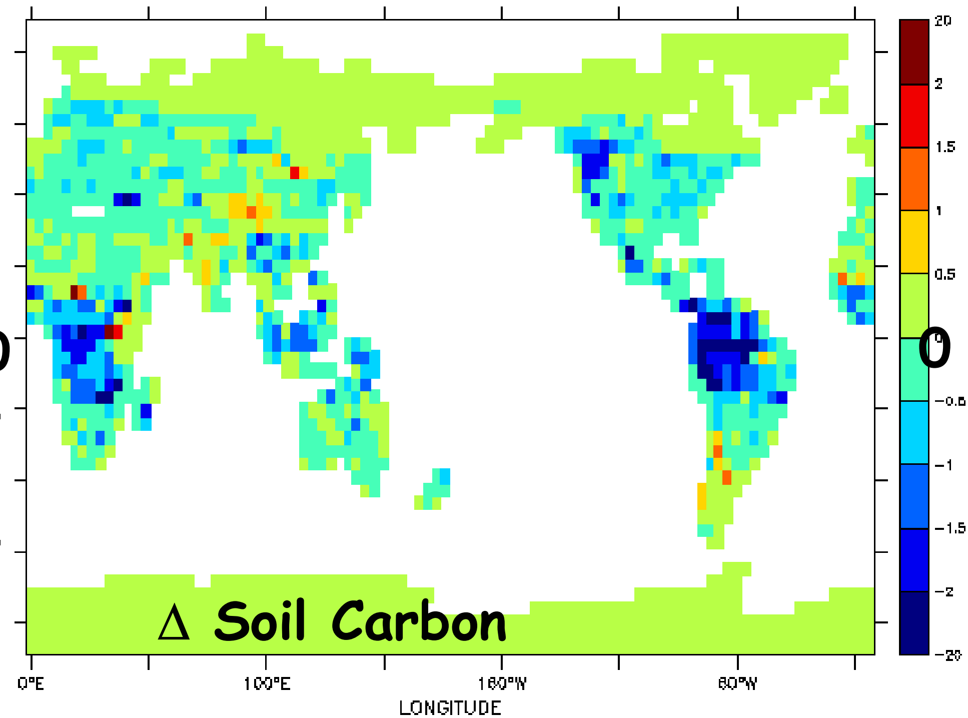

**Warm-wet**
**Cold-dry**

**Warm-dry**
**Cold-wet**

**Very warm and dry since 1998 (Hoerling and Kumar)**

# Changes in Veg and Soil Carbon:
## w minus w/o climate feedback




Warmer (drier) → decr NPP → Less above-grd biomass

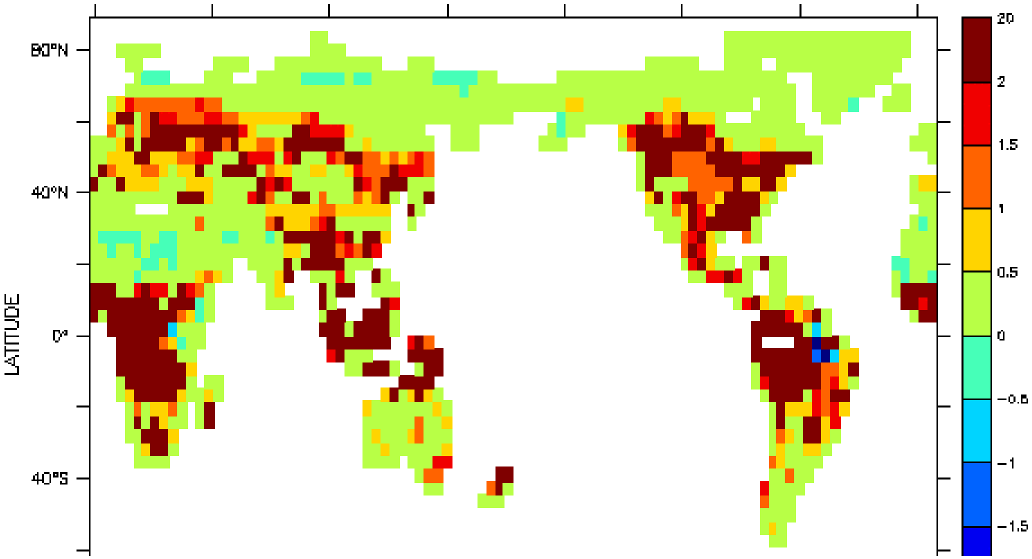
Less litter + faster decomp → Less below-ground biomass

Warmer (wetter) → incr NPP → more above-grd biomass

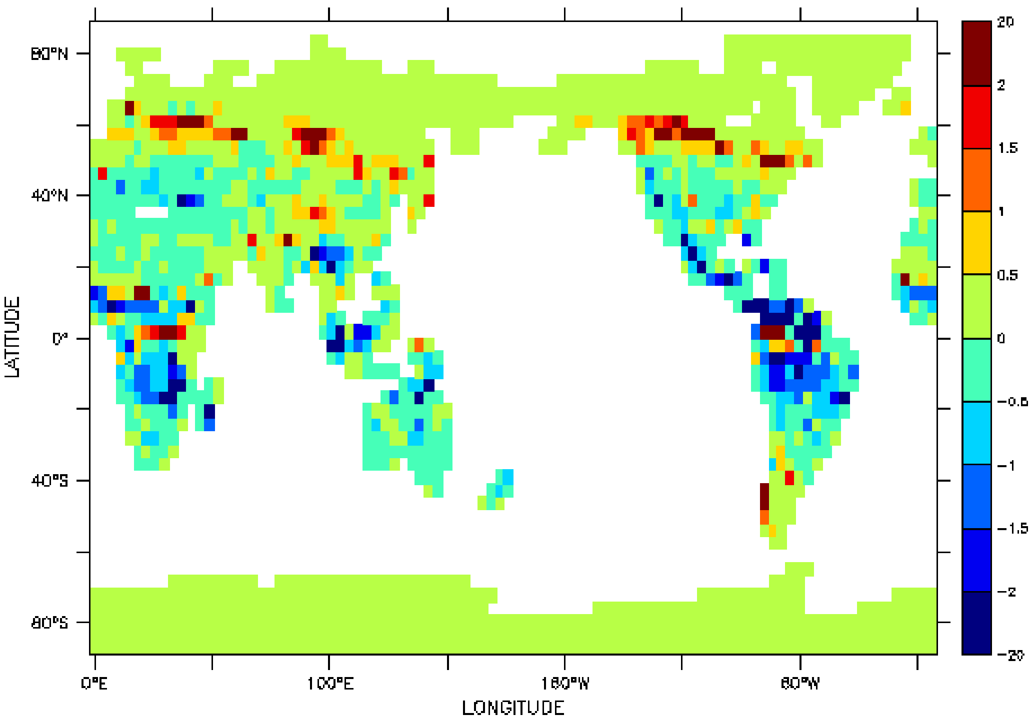
more litter + faster decomp → Less below-ground biomass

# Δ Biomass

**Biomass(2080-2100) minus Biomass(2000-2020)**




**$CO_2$Fert on, Rad_off:**
**ΔB incr almost everywhere**




C4.24b C4.25b totbiomass: L20-F20 (kg/m2)

**Rad_on minus Rad_off**

*(ΔB +ve for both cases)*

- **Tropics:**
  **less ΔB w climate fdbk**
- **Hi Lat:**
  **more ΔB w climate fdbk**
- **Global:**
  **less ΔB w climate fdbk**

# Summary: Positive but weak climate feedbacks

- Physical climate model NCAR-CCSM1 has low climate sensitivity d(Climate)/d($CO_2$)
- Locally:
    - Competing effects bet' T and moisture on biology
    - Short turnover time ($10^o$-$10^1$ yr) of vegetation carbon → tight NPP/resp. coupling through biomass (# of pools/effective turnover time)
- Regionally: Enhanced C source somewhere, and enhanced C sink somewhere else
- Increased stratification in ocean → reduce air-to-sea flux
- Decrease upwelling → reduced marine productivity
- Land and ocean uptake coupled:
    - If land uptake ↓ → atm $CO_2$↑ → ocean uptake ↑

# Challenge and Opportunity:

- **Need observations/theory about behavior of biosphere in new climate space**
- **Terrestrial and marine ecosystem response to changing resource limitation (macro and micro-nutrient)**
- **Degree of $CO_2$ fertilization? Saturation?**